The Secretary of Energy
Washington, DC 20585

July 31, 2006

The Honorable Richard B. Cheney
President of the Senate
United States Senate
Washington, D.C. 20510

Dear Mr. President:

The Energy Policy Act of 2005 (EPAct), Section 994, requires the Department of Energy to periodically review all of the science and technology activities of the Department in a strategic framework that takes into account both the frontiers of science to which the Department can contribute and the national needs relevant to the Department's statutory missions. As part of the review, the Department is required to develop a plan to improve coordination and collaboration in research, development, demonstration, and commercial application activities across Department organizational boundaries. The results of the review and the plan are to be submitted to Congress every four years, with the first submittal due not later than 12 months after the enactment of EPAct (Public Law 109-58, dated August 8, 2005).

In accordance with EPAct Section 994, the Department submits the enclosed report titled *DOE Strategic Research Portfolio Analysis and Coordination Plan*.

If you have any questions, please contact me or Ms. Jill L. Sigal, Assistant Secretary for Congressional and Intergovernmental Affairs, at (202) 586-5450.

Sincerely,

Samuel W. Bodman

Enclosure

The Secretary of Energy
Washington, DC 20585

July 31, 2006

The Honorable J. Dennis Hastert
Speaker of the House
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Speaker:

The Energy Policy Act of 2005 (EPAct), Section 994, requires the Department of Energy to periodically review all of the science and technology activities of the Department in a strategic framework that takes into account both the frontiers of science to which the Department can contribute and the national needs relevant to the Department's statutory missions. As part of the review, the Department is required to develop a plan to improve coordination and collaboration in research, development, demonstration, and commercial application activities across Department organizational boundaries. The results of the review and the plan are to be submitted to Congress every four years, with the first submittal due not later than 12 months after the enactment of EPAct (Public Law 109-58, dated August 8, 2005).

In accordance with EPAct Section 994, the Department submits the enclosed report titled *DOE Strategic Research Portfolio Analysis and Coordination Plan*.

If you have any questions, please contact me or Ms. Jill L. Sigal, Assistant Secretary for Congressional and Intergovernmental Affairs, at (202) 586-5450.

Sincerely,

Sam Bodman

Samuel W. Bodman

Enclosure

DOE Strategic Research Portfolio Analysis and Coordination Plan

Energy Policy Act, Section 994, Report to Congress

INTRODUCTION

The Energy Policy Act of 2005 (EPAct), Section 994, requires the Department of Energy (DOE) to periodically review all of the science and technology activities of the Department in a strategic framework that takes into account both the frontiers of science to which the Department can contribute and the national needs relevant to the Department's statutory missions. Additionally, and as part of the review, the Department is required to develop a plan to improve coordination and collaboration in research, development, demonstration, and commercial application activities across Department organizational boundaries. This plan is due to the Congress in a report not later than 12 months after the date of enactment of the EPAct (Public Law 109-58; August 8, 2005), and every four years thereafter, and must include the results of the Department's review and the Department's coordination plan.

This report has been prepared to meet the requirements of Section 994. It documents past approaches to coordination within DOE, the results of two recently completed portfolio reviews, and a preliminary plan for future coordination and collaboration that contains the elements prescribed in the Act. The corresponding relationship among the applied technology and science programs is developing well, spurred on by EPAct, and this emerging relationship holds the promise for substantial returns. Overall, the many efforts described within the pages of this report reflect a "work in progress." The report is organized around three chapters and includes an appendix that contains a list of acronyms. The three chapters are:

I. Integration Activities and Processes identifies how the applied technology and science programs are currently coordinating activities, not only across the basic-applied research divide, but also across the applied technology programs. Also included in this chapter are the Department's early assessments of ways in which technical interchanges could be enhanced, including ways in which the research agendas of the Office of Science (SC) and the applied programs could interact and assist each other.

II. Significant Crosscutting Scientific and Technical Issues summarizes the scientific and technical issues and research questions that span more than one program or major office of the Department based on the results of the S&T Program Reviews conducted by SC and the DOE R&D Council's assessment of the Department's energy and environmental portfolio.

III. Strategies for Implementation describes how the Secretary will ensure that the Department's overall research agenda includes, in addition to fundamental and curiosity-driven research, basic research related to topics of concern to DOE's applied technology programs. In addition, the

Secretary will ensure that DOE's overall research agenda includes applications in Departmental technology programs generated from the basic research agenda.

The portfolio reviews conducted in 2005-06 identified areas of mission risk and helped focus discussions on risk mitigation strategies, both in terms of what science can do for the applied programs and also in terms of what research in the applied programs can do for science…and for other applied programs. As a major science and technology agency, there is considerable focus within DOE on scientific discovery and technological innovation as pathways to deliver the long-term, enduring solutions for our growing national challenges in energy security, nuclear security, and environmental protection. Transformational innovation is needed if the Nation is to address such critical issues as U.S. dependency on foreign oil, proliferation of nuclear capabilities to unstable regions of the globe, mounting concerns over a changing climate, and creating a more efficient and responsive infrastructure to support the nation's nuclear deterrent in the absence of testing, to name a few.

The actions taken by the Department reflect a growing consensus among the Nation's top leaders that a business as usual approach will not meet our national challenges in a timely way and that changes are necessary, and in some cases, urgent. For example:

1) The President has strengthened the role of science through the American Competitiveness Initiative, including a long-term commitment to increased funding for the Office of Science given its critical role within the Federal government for supporting basic research in the physical sciences.
2) The Congress has enacted EPAct, Section 994, charging the DOE to improve research integration and the linkages between basic research and applied research programs. The Congress also created, in Section 1006, the new position within DOE of Under Secretary for Science, requiring that this Under Secretary serve as the Science and Technology Advisor to the Secretary.
3) The Secretary of Energy has championed research integration and the role of science as a way to accelerate DOE mission accomplishment and has launched numerous efforts designed to increase cooperation among R&D programs and bring a scientific perspective to bear on complex technological challenges. For example, advice and support from SC was sought in such areas as the National Ignition Facility, stockpile stewardship, environmental management, the Hanford vadose zone, hydrogen storage, the Global Nuclear Energy Partnership, and solar power.
4) The Under Secretary for Energy and the Environment, overseeing the Department's R&D Council, launched an evaluation of the energy S&T portfolio in 2005 as part of the Department's annual budget process, exploring portfolio gaps and analyzing opportunities from the standpoint of S&T program cooperation and integration.

The value of improving research integration has been widely accepted within the Department, but the practical matter of working across diverse cultures driven by different interests and missions poses significant challenges. As a result, the Department realizes that sustaining momentum and progress requires a different level of commitment and exploration of underlying issues, incentives, and management structures.

Emerging areas of science promise discoveries and breakthroughs that can help achieve accelerated technological advances for the Department's applied mission goals. Powerful advances in computation and simulation are redefining how we pursue discovery. Such advances have positioned computational simulation on an equal footing with theory and experiment, ushering in radically new possibilities for the pursuit of new knowledge.

At the same time, powerful scientific probes now enable scientists to understand and manipulate matter at the atomic and molecular scales, enabling the design of new materials, and thus solutions, "atom-by-atom." In addition, the advanced major research facilities for science – the Spallation Neutron Source, advanced fusion facilities (ITER/NIF), advanced light sources, nanoscale science research centers, genomic sequencing centers, high-end computational centers, accelerators, environmental science, and more – are the great enablers that are the source of optimism that solutions may be on hand for some of our most challenging national issues.

I. INTEGRATION ACTIVITIES AND PROCESSES

The integration of DOE R&D programs has been ongoing since the Department was formed in 1977. These integration efforts range from highly structured working arrangements between basic and applied DOE programs, such as jointly planned technical workshops focused on major Administration priorities, to informal yet critically important mechanisms such as the funding at a national laboratory of a principal investigator who, for multiple DOE sponsors, is working on both basic research and application. Taken in sum, these integration activities are widespread and have contributed greatly to DOE's capabilities.

DOE's current structured integration efforts include the formation of integrating oversight groups, such as the R&D Council, as well as specific mechanisms such as sponsorship (or joint sponsorship) of technical workshops on integrated topics, S&T roadmapping exercises spanning science and technology topics, jointly coordinated and funded R&D programs, program reviews with a focus on crosscutting R&D opportunities, and use of DOE's scientific user facilities. The following Table summarizes some of these mechanisms and provides supporting discussion. This set, although not comprehensive, is representative of the many activities and types of mechanisms deployed historically at DOE to help achieve research integration.

Mechanism	Examples	Description
Technical Workshops	The Role of the Nuclear Physics Research Community in Combating Terrorism (July 2002) Basic Research Needs to Assure a Secure Energy Future (October 2002) Basic Research Needs for the Hydrogen Economy (May 2003) Nanoscience Research for Energy Needs (March 2004) Advanced Computational Materials Science: Application to Fusion and Generation IV Fission Reactors (March 2004) Basic Research Needs for Solar Energy Utilization (April 2005) The Path to Sustainable Nuclear Energy: Basic and Applied Research Opportunities for Advanced Fuel Cycles (September 2005) Biomass to Biofuels Workshop (December 2005) Basic Research Needs for Superconductivity (May 2006) Basic Research Needs for Solid-state Lighting (May 2006) Basic Research Needs for Advanced Nuclear Energy Systems (July 2006) Basic Research Needs for Energy Storage (Summer 2007) Basic Research Needs for the Clean and Efficient Combustion of 21st Century Transportation Fuels (October 2006) Basic Research Needs for Geosciences (Spring 2007)	One of the primary mechanisms for research integration is the use of highly structured and jointly planned technical workshops. The end product is a consensus opinion from DOE basic and applied research programs about the direction that should be taken in a particular area. Technical Workshops typically result in a wide range of activities, including jointly held program meetings, co-funding of R&D opportunities, and roadmaps. The Workshops can also tie into structured initiatives such as FreedomCAR and Gen-IV.
Roadmaps	Carbon Sequestration Magnetic and Inertial Confinement Fusion	Roadmaps typically follow a Technical Workshop and can take many different forms, but generally outline the science and technology

	Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda	pathways that could be pursued to achieve a specific mission goal. Roadmaps typically contain off ramps for R&D options that depend on the perceived merits of various technical directions.
Structured Efforts	• Biomass (including cellulosic ethanol) • Buildings (including solid state lighting) • Solar • Vehicle technologies (including Freedom Car) • Hydrogen • Industry • Advanced Fuel Cycle • Generation IV Nuclear Energy Systems	Administration and Congressional priorities often enable the DOE to focus resources internally and externally to maximize R&D programs. This is accomplished by holding program-to-program workshops, program manager meetings, and co-funding and co-location of research projects at a national laboratory or university. These efforts are described in more detail throughout this Report.
Technical Working Groups	Energy Materials Coordinating Committee (EMaCC) Interagency Working Group on Metabolic Engineering (MEWG) Interagency Working Group on the Physics of the Universe Task Force on High Energy Density Physics of the Universe	DOE program managers have established formal technical coordinating committees that meet on a regular basis to discuss R&D programs that have wide applications for basic and applied programs. The EMaCC is the longest standing of these kinds of committees, but past topical areas have included combustion, biofuels and advanced computation. Current EMaCC representatives are from SC, FE, EE, NE, EM, OE, NN and RW. The MEWG is an example of an interagency group that has an SC participant (BER) and an applied program (EERE). The MEWG sponsors meetings, seminars, annual workshops and funding of peer-reviewed projects. OSTP typically organizes these and other interagency working groups. The Interagency Working Group on Physics of the Universe, chartered by the National Science and Technology Council (NSTC), has completed several major reports describing a coordinated interagency approach to address the key intellectual questions on the origin and evolution of the universe. Results are presented in the NAS report entitled, "Connecting Quarks to the Cosmos." Also chartered by the NSTC, the High Energy Density Physics Task Force is developing an interagency approach for strengthening the field and increasing scientific opportunities within it.
Portfolio Reviews	Energy S&T Portfolio Reviews (2005/2006) (See Chapter II) Department-wide Program Reviews for Research Integration (2006) (See Chapter II)	Portfolio reviews, particularly when they are linked to the DOE corporate budget process, can be highly effective ways to promote research integration. The DOE R&D Council sponsored such a portfolio review in 2005 and 2006. The 2006 review was complemented by the SC Program Reviews conducted in May 2006.
User Facilities	Combustion Research Facility Computational Centers Accelerators Atmospheric Radiation Measure facilities JGI Production Genomics Facility The "Mouse House" Environmental Molecular Sciences Laboratory Light Sources	DOE's large scale scientific user facilities are centers for multidisciplinary research and integration between basic and applied research. The Combustion Research Facility, for example, annually supports research projects involving scientists from industry, academia and national labs who are sponsored by DOE applied and basic research programs.

	Neutron Sources Nanoscale Science Research Centers	
Collaboratories	Particle Physics Data Grid Collaborative Pilot Earth System Grid II National Fusion Collaboratory Collaboratory for Multi-Scale Chemical Science	Through collaboratories, researchers share access to computational facilities, large datasets and information technology environments; support the frequent interactions needed to address complex problems; and, speed up discovery and innovation. DOE is promoting the advancement of collaboratories through a series of research projects, both as a major component of the Scientific Discovery through Advanced Computing (SciDAC) program, and as an element of the base program. These projects are providing the essential infrastructure, middleware technologies, and collaboratory experience needed to bring collaboratories into the mainstream of day-to-day research in DOE and elsewhere.
Joint Solicitations	BER/FE on Carbon Sequestration (FY07) DOE/NSF Program in Plasma Physics Small Business Innovative Research Program (SBIR) Small Business Technology Transfer Program (STTR) DOE Experimental Program to Stimulate Competitive Research (EPSCoR)	Joint program planning that leads to joint solicitations for R&D proposals from national labs, universities and industry has been used to accelerate R&D and improve the handoff between basic and applied programs. The DOE/NSF plasma effort is jointly funded by SC and NSF and has been very successful in supporting basic plasma physics at universities, which in turn support NNSA plasma physics efforts. The SBIR, STTR and EPSCoR programs are examples of highly structured annual solicitations that cross program boundaries and encourage joint planning of targeted research topics. The EPSCoR program, for example, is managed by SC, but annually engages program managers from other DOE office in the review and co-funding of successful projects. Current technology office projects include: FE (distributed generators); NNSA (robust x-ray radiographic devices); and EERE (utilization of biomass).

These structured efforts are often combined to achieve the long-term mission goals of the Department. For example, DOE's R&D program in carbon sequestration dates back to a 1997 DOE-sponsored international workshop which resulted in a report entitled, "Fuels Decarbonization and CO2 Sequestration", and to a technical workshop that occurred in 1999 which produced a roadmap, "Carbon Sequestration Research and Development." These efforts have led to jointly coordinated and funded R&D programs that began with modest funding and continued to grow rapidly. For example, cumulative funding since 1999 for applied R&D sequestration activities totals nearly $260 million, including over $66 million in FY2006 supporting about 70 projects. There has also been significant funding during this period for applicable science research.

Further, SC national laboratories contribute to DOE's carbon sequestration program by providing expertise in hydrogeology, geochemistry, geophysics, modeling and simulation, instrumentation, ecology, soil mineralogy and other science areas of importance to applied technology programs. A core R&D program and infrastructure development program consisting of seven regional partnerships are contributing to the Department's FutureGen project. Most recently, SC and the Office of Fossil

Energy (FE) have planned a joint solicitation for Fiscal Year 2007 that would enable computing applications that track the fate of carbon dioxide, perform risk assessment and provide quick response approaches.

Described below are eight examples of structured DOE efforts that illustrate the Department's commitment and recent accomplishments over our recent past in pursuing mission goals and reducing mission risk through an integrated research approach. In no specific order, these examples include:

- Biomass (including cellulosic ethanol)
- Buildings (including solid state lighting)
- Solar
- Vehicle technologies (including Freedom Car)
- Hydrogen
- Industry
- Advanced Fuel Cycle
- Generation IV Nuclear Energy Systems

Biomass (including cellulosic ethanol) - Cellulosic ethanol from biomass is one of the pillars of the Presidential Advanced Energy Initiative (AEI). Designed to reduce U.S. dependence on foreign oil, breakthroughs in biological sciences (including genomic science) and applied research have resulted in significant new opportunities and potential efficiencies that bring this goal within reach. However, significant technical barriers remain to realizing the enormous commercial potential of cellulosic ethanol and collaboration between the basic research and applied research communities is critical to position this technology to move forward. The Office of Biological and Environmental Research (BER) and the Office of Energy Efficiency and Renewable Energy (EERE) are working together, including cooperation on a Biomass to Biofuels Workshop (December 2005) and a corresponding roadmap that is nearing publication. Promising future areas that have been discussed as potential, logical extensions to collaborations include both mid-term and long-term components. Mid-term technology focus areas include feedstock use and optimization, cell wall deconstruction, and fermentation and recovery. Longer-term research will focus on process integration and consolidation, as well as the use of genomics for domestication of a new suite of sustainable energy crops. Specific long-term areas of interest include: *feedstock genomics, metabolism, photosynthesis; cell wall structure, physiology, etc.; enzyme development, biocatalysis; fermentation organism development for cellulosics, hemicellulosics; single reactor saccharification, hydrolysis, and fermentation*.

Buildings (including solid state lighting) - Residential and commercial buildings, together, are the largest users of energy in the U.S. There exist considerable opportunities to continue to increase the energy efficiency of buildings through collaborative R&D. Past successes between the basic and applied research programs are numerous, with significant accomplishments in such areas as LEDs, OLEDs, structural materials, smart materials and windows, and sensors and controls, to name a few. As recently as May 2006, EERE and SC conducted a joint workshop on solid state lighting. There has also been strong collaboration on SBIR/STTR, with 25 phase I and eight phase II projects. Future, promising areas for collaboration have been discussed as potential logical extensions to ongoing work. Candidates include: *advances in solid state lighting (materials science for GAN or other materials); research into advanced cooling technologies such as thermotunneling, thermoelectric materials, thermocaloric materials, and thermomagnetic materials; and dynamic and highly insulating windows (e.g., electrochromic materials)*.

Solar – The cost of solar energy production has been steadily decreasing for several decades, owing in large part to the technological advances brought about by the EERE and SC and their collaboration. With developments in thin film technologies and advances in nanoscience and new "designer" materials, the possibilities for even greater efficiency improvements seem very likely, as do the prospects for solar to assume a significant and expanding role in the U.S. energy future. The basic and applied R&D in SC/Office of Basic Energy Sciences (BES) and EERE, respectively, support the President's Solar America Initiative to make solar energy competitive in the national energy mix. Integration of research activities will provide a critical opportunity to link the science-intensive research capabilities with the applied solar research activities within the Department. Past successes included joint workshops and cooperation leading to the development of a world record 39% efficient concentrator cell. Future, promising areas that have been discussed as possible extensions to ongoing collaborations include*: properties of thin film materials, including the physics of CIS nanostructure domains; first-principle calculations of compound semi-conductor band-structure and other properties; physics of crystalline/nanocrystalline heterojunctions; interface physics of small organic molecules (organic heterojunctions); novel bandgap-engineered materials, e.g., quantum-dot materials allowing enhanced impact ionization; thermal storage materials for Concentrating Solar Thermal Power Systems; and power electronics*.

Vehicle Technologies (including Freedom Car) – The transportation sector accounts for fully 28 quads of U.S. energy consumption (excluding on-site transportation use in the industrial sector) and current forecasts are for continued rapid expansion through 2025. This sector is 96% dependent on oil and, as such, represents a significant area of opportunity to reduce dependency on foreign oil. There are significant opportunities to increase efficiencies and switch to alternative energy supplies that will only be realized through continued research and, more specifically, cooperation between the basic and applied research communities. Past successes and cooperation have been realized through the Combustion Research Facility at the Lawrence Livermore National Laboratory (LLNL) and at the Advanced Materials Lab at the Oak Ridge National Laboratory (ORNL). Past cooperation has also been achieved in such areas as battery technology, composites, materials for extreme conditions, welding and joining, and more. Based on past and ongoing cooperation, areas for potential expanded cooperation include: *combustion modeling; sensors for high temperature environments; heat resistant materials; energy storage (nanomaterials and chemistries for next generation high energy batteries); computational modeling of materials for energy conversion and energy storage, including batteries and super-capacitors); nanostructured high efficiency thermoelectrics; and chemistry of fuels from emerging feedstocks (e.g., biomass)*.

Hydrogen – America currently imports 55$\pm$ percent of the oil it consumes; that is expected to grow to 68 percent by 2025. Two-thirds of the 20 million barrels of oil Americans use each day is used for transportation. Hydrogen has the highest energy content per unit of weight of any known fuel and can be produced using abundant domestic energy resources including fossil, nuclear, and renewable. Continued research is needed to reduce the cost and improve the performance of hydrogen production, storage, deliver, and fuel cell technologies to enable their commercial viability and realize the goal of achieving mass commercial introduction of hydrogen fuel cell vehicles into the market by 2020 and the long-term goal of significant replacement of conventional technologies in our Nation's vehicle inventory by 2040. DOE's basic and applied research communities have integrated the planning and implementation of hydrogen and fuel cell activities through joint workshops and annual program reviews, and through the development of the Hydrogen Posture Plan. Expanding from ongoing areas of cooperation, areas of future interest include*: hydrogen storage materials, including metal hydrides, chemicals, carbon-based, and new materials; fuel cell materials, including membranes, non-precious metal catalysts; nanomaterials for ultra-high power density fuel cells; and hydrogen production drawing on thermochemical, electrochemical, biochemical, photolytic, and other processes*.

Industry - U.S. industry consumes nearly 33 quads of energy each year, more than a third of all energy used in the United States. The DOE conducts research and works with industry to reduce the energy intensity of manufacturing processes. Significant ancillary benefits are realized with reduced use of toxic feedstocks, reduced emissions and by-products, reduced production costs, and increased industrial competitiveness. Most industrial facilities harbor significant opportunities for energy savings and continued research is needed. In particular, cooperative research between SC and EERE are expected to pay large dividends as we enter a new era of materials science, biology, and computational sciences that have the ability to transform industrial processes as we now know them.

Cooperation in the past has yielded many successes, including joint development of nickel aluminides (ORNL); palladium-nickel alloys for hydrogen sensing (SNL); lost-foam casting (SC/University of Alabama); and numerous developments from SBIR/STTR joint work. Future, promising areas for collaboration have been discussed as potential logical extensions to ongoing work. Candidates include: *reaction and separation technologies, including those for high temperatures and catalysis; computational fluid dynamics, especially for multiphase flows; nanostructured materials; manufacturing technologies for the scale-up of production of nanoscale materials and their ultimate application in energy technologies; alloy chemistry and processing; non-destructive evaluation of properties; combustion science with reduced emissions; sensors for high temperature and/or corrosive application; inferential sensing and control at the micro-scale level of manufacturing processes; and biocatalysis and bioprocessing in specific low temperature conversion processes.*

Advanced Fuel Cycle - The mission of the Advanced Fuel Cycle Initiative (AFCI), now part of the FY 2006 initiated Global Nuclear Energy Partnership (GNEP) program, is to develop technologies that will meet the need for economic and sustained nuclear energy production while satisfying requirements for a controlled, proliferation-resistant nuclear materials management system. The primary near-term goal of the AFCI program has been to develop and demonstrate advanced, proliferation-resistant fuel cycle technologies for treatment of commercial light water reactor spent fuel, to develop an integrated spent fuel recycling plan, and support initiation of processing and fabrication demonstrations . In the longer term, AFCI's development supports a system involving spent-fuel partitioning and recycling of actinides and other long-lived radioactive components in fast reactors for destruction through transmutation. The Office of Science has helped in the establishment of NE's Nuclear Energy Research Initiative and cooperation between these two programs continues to evolve and strengthen, with key areas and recent successes centered around relevant materials research. As a result of recent meetings between members of the Office of Science and AFCI, several major areas have been identified where increased cooperation between the two offices can have major payoffs. These areas include, but are not limited to*: research to reduce uncertainties in certain actinide cross sections that are needed to precisely analyze the closed transmutation fuel cycle; advanced monitoring technologies for near real-time chemical and isotopic analyses of flowing streams in separations facilities; advanced analysis tools for more rapid design and analysis of transmuting fast reactors; and the development of advanced, powerful simulation and modeling tools to accurately predict reactor and fuel performance behavior in order to reduce the need for lengthy irradiation campaigns in test reactors.* Later in this fiscal year three formal workshops are planned by the Office of Science to further refine suggested areas of collaboration and to chart a course forward.

Generation IV Nuclear Energy Systems - Both the President's National Energy Policy and the EPAct recognize the potential for nuclear energy to help meet our nation's growing need for safe, reliable, and environmentally responsible energy supply. The goal of the Generation IV Nuclear Energy Systems Initiative is to address the fundamental research and development issues necessary to establish the viability of next-generation nuclear energy system concepts. Successfully addressing the fundamental research and development issues of Generation IV system concepts that excel in safety, sustainability, cost-effectiveness and proliferation-resistance will allow these advanced systems to be considered for future commercial development and deployment by the private sector. Over the past three years the Office of Science and the Office of Nuclear Energy (NE) have collaborated on five SBIR grants in the area of nuclear materials research. Future areas of cooperation between NE and SC include the *application of massively parallel supercomputing technologies in the analysis of reactor fuels and materials performance issues in order to substitute computation and simulation for lengthy experimentation. Additionally, the development of instrumentation and controls that may have common applications in both fusion and fission systems is another example of where basic research can benefit applied technologies.*

In addition to the integration mechanisms and the specific examples described above, a variety of informal integration activities routinely occur at the Department. These include personnel exchanges between DOE R&D programs, principal investigator to principal investigator interactions, and DOE program manager planning meetings. DOE's technology program managers, for example, regularly meet with their counterparts in the Office of Science to discuss R&D planning efforts on crosscutting issues such as high-temperature superconductivity, hydrogen, climate change, environment and other major efforts.

In order to fully understand the scope and dimensions of these integration mechanisms and activities, and complementing the May 2006 Program Reviews, a separate integration workshop was held to review past integration efforts, to assess their effectiveness, and to develop ideas for improving the process. Some of the conclusions from that workshop were:

- *Involving senior management* in scientific and technical discussions is critical to the success of research integration. The reviews of technology programs led by the Director of the Office of Science in May 2006 produced 21 areas of potential collaboration between basic and applied research programs that are discussed in Chapter II of this Report. A number of these opportunities had not been identified prior to these reviews.

- *Avoiding "impedance mismatches"* between basic and applied research programs enables a more efficient handoff of research results between programs. One of the findings of the May 2006 DOE Program Reviews was that DOE's basic and applied programs must be better coordinated to ensure that there can be effective cooperation among the organizations. For example, if the applied or basic research program does not maintain an adequate base of funding or technically qualified program managers, an impedance mismatch can occur that will make it difficult, if not impossible, for basic research to be properly focused and the discoveries assimilated by the applied program. Research initiatives should be structured in a way that enables productive interfaces and effective integration among the participating programs. Communication and upfront planning helps ensure that this "handoff" will occur.

- *Technical Workshops* enjoy a special role as launching venues for crosscutting efforts. When combined with a technology roadmap or other follow-up plan which includes technical milestones, review points, etc., the results from Technical Workshops can be long-term and sustained. The primary product of the Technical Workshops – a consensus report developed by the basic and applied research communities – is used to identify complementary research opportunities and possible intersections.

- *Developing incentives* to promote integration will help institutionalize research integration efforts. These incentives should be oriented toward promoting mission success and would include increased funding for highly performing programs, incorporating R&D integration into program and manager performance reviews, and providing greater visibility of DOE's R&D integration activities with the Office of Management and Budget (OMB) and the Congress. It is widely believed that R&D programs that have strong linkages between basic and applied research efforts will prove to be more successful in the long run and should be highly encouraged.

The aspects of R&D integration discussed above are generally considered by DOE program managers to be the foundation for a fully successful R&D portfolio. These preliminary conclusions, however, will be validated through experience and further evaluation during Fiscal Year 2007 to ensure that DOE's portfolio is optimally managed.

II. SIGNIFICANT CROSSCUTTING SCIENTIFIC AND TECHNICAL ISSUES

In response to EPAct, and consistent with the broader interest by DOE's senior leadership to improve research integration within the Department, two significant efforts were launched to identify gaps in DOE's S&T portfolio, with a particular emphasis on areas of crosscutting interest and the potential for achieving mutual benefits among DOE's major programs. One was a targeted, in-depth energy portfolio review backed by detailed analysis. The second was a broad based effort looking at research integration across all major S&T program elements conducted under the auspices of nine separate Program Reviews. These two efforts, and the significant findings from both, are described below.

It should be noted that each of these efforts had a significantly different focus and scope, and the approaches were fundamentally different. Thus, while there is overlap, there is useful information contained in the similarities as well as the differences in opportunities identified through each process. Also, the set of opportunities should not be perceived as comprehensive. At the very least, they supplement many significant activities already underway. Even as a list of future promising activities, collectively they represent a partial list, albeit a high priority list based in part on analysis and part on judgments about requirements, resources, risks, and uncertainties for the future.

Energy S&T Portfolio Review

In fall 2005, the DOE launched a review under its R&D Council that assessed the energy S&T portfolio's potential impacts on the Nation's energy goals and identified the primary scientific and technical challenges that must be met by DOE programs to achieve the Department's energy objectives. That review consisted of a balanced look at major technology research needs (representing challenges for the science community), areas where science might create fundamentally new options and technologies, and areas of technology investment that could help accelerate the development and market acceptance of commercially viable, improved energy options.

The initial analytical effort was largely undertaken by the Laboratory Working Group, a collection of the deputy directors in both science and technology from each of the major DOE national laboratories, and was complemented by an Integration Working Group of Federal analysts. The final product was delivered in a senior level briefing by the Under Secretary for Energy and the Environment, and the Under Secretary for Science. Significant opportunities identified through that effort are noted in the table below, and in all three categories, the mutually supportive, collaborative roles of the various science and technology programs are identified in the detailed briefing materials.

R&D Council Energy Portfolio Assessment: Recommended Specific Areas for Investment and/or Management Attention

Resource Allocations

- Electricity storage
- Carbon capture & storage
- Unconventional fossil
- Bioenergy (including cellulose to ethanol)
- Adaptive grid controls
- Power electronics
- Superconductivity
- Solar energy utilization
- Buildings systems
- Complex systems assessment

Integrated Basic-Applied Research

- Hydrogen storage
- Advanced nuclear fuel cycle
- Synthetic & systems biology
- Chemical transformation, catalysis and control

Better S&T Communication

- Advanced computing
- Advanced materials

Department-Wide Program Reviews for Research Integration

The Department also conducted nine Program Reviews led by the Director of the Office of Science (now the Under Secretary for Science) of DOE's applied research and technology programs. These senior level meetings provided an opportunity for DOE's applied research and technology programs to identify and discuss their mission-related challenges and mission risks with the Office of Science and other applied programs. These meetings were open to every program and the resulting meeting dynamics created considerable opportunity to capitalize on technology-to-technology program cooperation, not just science-to-technology program cooperation.

Reviews were conducted with all of the DOE applied research programs. Of particular note was the participation by the two organizations within the National Nuclear Security Administration (NNSA) that have primary responsibility for security-related research and development. In addition, all six Office of Science research programs – Advanced Scientific Computational Research (ASCR), Basic Energy Sciences (BES), Biological and Environmental Research (BER), Fusion Energy Sciences (FES), High Energy Physics (HEP), and Nuclear Physics (NP) – participated in the Program Reviews. The participating technology programs were:

- Office of Civilian Radioactive Waste Management
- Office of Electricity Delivery and Energy Reliability
- Office of Energy Efficiency and Renewable Energy
- Office of Environmental Management
- Office of Fossil Energy
- National Nuclear Security Administration – Nuclear Nonproliferation
- National Nuclear Security Administration – Defense Programs
- Office of Nuclear Energy
- Office of Security and Safety Performance Assurance

As a result of these Program Reviews, more than 200 discrete opportunities for mutual collaboration were brought to the table through briefing materials and/or were discussed in the Program Reviews. Of that expansive set, the following 21 items were identified as having the best opportunity to increase mission success or were previously unidentified opportunities for mutual collaboration.

This does not imply that the other items were not important or that they will not be pursued. Rather, it means that for this first cycle, DOE management felt that such a number was manageable and could lead to a successful launching of a structured integration process. In addition, experience with these 21 collaboration opportunities will enable DOE to more accurately assess the potential of this approach and ways to more effectively improve research integration.

Following are the 21 areas of opportunity and summary descriptions organized into four mission-related categories. The categories are: *highly crosscutting, energy, national nuclear security, and environmental management*.

HIGHLY CROSSCUTTING

1) Radiation-Resistant Materials

Implications: There is a significant opportunity to respond to multiple departmental (and national) mission challenges by capitalizing on the advances in materials science to understand and design materials for the challenging, extreme conditions of radiation environments. The DOE has multiple challenges from the standpoint of stockpile stewardship; challenges for design and safety assurance of next generation and advanced reactor concepts (including fuel cycle issues); challenges in waste storage, treatment and containment issues for materials; and even DOE's basic research programs are challenged in the design and operation of many facilities, including, perhaps, the ultimate challenge of designing a fusion power facility that can withstand the intense radiation fluxes, temperatures and pressures of a sustained burning plasma. Outside the Department, NASA, DOD, and others are faced with no less a daunting challenge. Significant advances in materials science, computational science, and other related disciplines provide the launching point for a broad-based national program that can respond to these mission challenges with collective focus and effort. Such a program will not only help reduce uncertainties in predicting long-term performance, but will undoubtedly deliver new classes of materials with greatly improved performance for those many applications where needed.

Promising focus areas: Current processes of "cook and look" with regard to materials synthesis and processing need to give rise to more predictive understanding of materials properties under extreme conditions and many research opportunities are now possible with improved materials science, computational algorithms, and 200 Teraflops sustained computational speeds that are now achievable. There is opportunity to develop quantum calculations for bond strength in real time, and building simulations from atomic scale effects to the bulk properties of materials under extreme radiation and other conditions. There is interest in low atomic weight materials, silicon carbides, and more generally, in inherently radiation-temperature-chemically resistant materials.

2) Energy Storage

Implications: Energy storage for a wide range of power levels and mission duty cycles is needed. Large scale electricity storage will benefit the grid in cost effective applications by making it more reliable, reduce system transmission congestion, help manage peak loads and shift from expensive peaking to more efficient base-load generation, and make many renewable electricity sources more viable. At the mid-scale, there are significant implications for hybrid and plug-in electric vehicles, as well as innovative concepts for an integrated vehicle-based battery grid storage system. Advanced battery technology developed for hybrid and plug-in vehicles will likely benefit hydrogen fuel cell vehicles as well. Widespread commercialization of hydrogen-powered vehicles will support our national security interests by reducing and ultimately eliminating our reliance on foreign oil. On-board vehicle hydrogen storage is one of the critical barriers to the viability of hydrogen-powered vehicles. At the small to micro scale, independent power supplies for electronics and sensors are needed. Other forms of energy storage are also important, including potential forms of concentrated solar-thermal storage and hydrogen storage.

Promising focus areas: Opportunities for fundamentally new materials and integrated designs to achieve high cycle life, high energy capacity storage materials. In particular, there are now opportunities to create designer materials at the molecular level that would usher in a new class of high-cycle, high-density electric batteries that could revolutionize the transportation sector and the grid. Miniature, high density power supplies for personnel would support some of the DOE's safeguards and security needs.

3) Advanced Mathematics for Optimization of Complex Systems, Control Theory, and Risk Assessment

Implications: DOE's large scale computation efforts have historically focused on the techniques required for solving partial differential equations in areas such as fluid dynamics, material characterization and magneto hydrodynamics. But the math required for combining these and other models into complex systems, and for control theory and risk assessment are fundamentally different than what DOE has historically pursued and further development would benefit DOE in many of its other complex systems challenges. Examples include: the control and stability of the electric power grid, optimization of combustion systems and industrial processes, and full lifecycle optimization of nuclear fuel cycles with recycling. In support of the many integration efforts defined below that are dependent on advanced computation and simulation, this particular area of cooperation is foundational for those others and will help to advance progress on those many mission-related fronts.

Promising focus areas: Opportunities for breakthroughs in the behavior and mathematics of complex systems and multi-scale analysis. These breakthroughs would enable fundamentally new computational methods for modeling such systems. These complex systems that would be modeled include the national electricity grid, nuclear fuel cycle, fusion burning plasmas, carbon sequestration and methane hydrate risk analysis, and smart sensors.

4) Building Synergies With Work-for-Others, Laboratory Directed Research and Development (LDRD), and DOE University-Sponsored Research

Implications: There is considerable investment at our national laboratories by non-DOE entities, such as other agencies. There is also significant investment of discretionary money by the operators of the national laboratories, and the DOE invests significant resources in universities in support of its mission-related research. Recently, the Department has taken steps to improve its view of the DOE-sponsored work at its laboratories in context of the labs operating as a system. An important next step in the progression is to expand this systems-oriented perspective to other work underway at the labs and to the DOE's other sponsored research providers, that is, the nation's universities, to explore the linkages and opportunities for collaborations and broader synergies among the various interests and players.

Promising focus areas: An inventory and portfolio analysis of all related work within a context of integrated core competencies and from the standpoint of potential synergies across sponsors and research providers.

ENERGY

5) Superconductivity

Implications: Realizing a 100-fold increase over the capacity of conventional copper wires at a comparable cost will enable the transmission of more power through a smaller footprint, shrink the size of high temperature superconducting power equipment (smaller motors, etc.), and offer improved energy management capabilities (e.g., fault current limiters). There are particularly promising applications for urban settings for power distribution and for long-distance transmission. Novel, extremely strong and highly conductive wires constructed from nano-materials show considerable promise to revolutionize the grid.

Promising focus areas: Methods to reduce costs and control quality of superconducting wires require basic research. Some areas to consider include control of nano-defects and interfaces, filament development, high temperature superconducting film deposition rates, and more. For motors, generators, and other devices, work is needed on high voltage dielectrics.

6) Power Electronics/Switching

Implications: For the electric grid, advances will allow precise and rapid switching and control of electric power to support long distance transmission. Such advances are needed to more rapidly respond to system disturbances and allow the system to operate with lower margins and fewer constraints. There are broad implications for other energy-related applications such as hybrid electric vehicles, consumer electronics, industrial processes, solar energy, wind energy, buildings applications, as well as military-related applications. Power electronics that can withstand high temperatures, pressures, corrosive environments, and other challenging circumstances are needed for industrial technology processes, geothermal down-hole activities, and elsewhere.

Promising focus areas: This area is ripe for both basic and applied research, with properties of new materials observed such as silicon carbides and diamond-graphite nano-materials that, in the latter case, can deliver switching speeds that are 3x faster than present materials. Such materials must also withstand extremely high temperatures and harsh environments. New DOE Nanoscale Science Research Centers can help facilitate the needed breakthroughs. These breakthroughs will enable new, higher power systems to be implemented across the grid, improving control and grid efficiency. Additionally, work by the basic research community in high energy physics on International Linear Collider power modulators is likely to be relevant.

7) Grid Control

Implications: Significant improvements are needed to improve grid reliability and efficiency, increase utilization of assets, reduce vulnerabilities, and accommodate expected significant changes and adaptations to changing energy supplies/demands. Efforts are needed for much more rapid and reliable detection of disturbances and prevention of widespread outages and cascading blackouts while providing real-time information during energy emergencies. Development of renewable energy resources and accommodation of decentralized energy sources will require a systems perspective and modeling approach.

Promising focus areas: Mathematics underlying these complex, interconnected systems is poorly developed and does not support predictive understanding, modeling, and control. Further development of the math and models of such complex systems is critical to improving the speed and effectiveness of grid management control systems. Similarly, improved visualization techniques will help in the human interface with such control systems.

8) Wind Power

Implications: Although wind power is one of the more mature renewable technologies, there remain significant opportunities to improve cost and performance, particularly in low wind-speed regimes, as well as technical uncertainties associated with wind patterns, both at a micro- and macro- scale that could impact not only siting decisions, but many other operating and design features. Both areas could benefit from increased science attention.

Promising focus areas: Continuing to reduce the cost of wind energy and enabling the cost-effective use of more wide-spread but lower-speed wind resources will require further improvements in the efficiency of wind turbines and reductions in their capital cost by reducing the material required in their construction as well as improved knowledge of wind patterns. To address these needs will require further collaborations to better characterize the fundamental aerodynamics of rotating airfoils, especially effects caused by inflow turbulence; this can help optimize turbine rotor efficiency and mitigate loads, reducing materials requirements. Characterizing wake mixing, and downstream impacts, aeroacoustics, and developing better and higher resolution wind models that integrate with long-term assessments of potential changes in wind patterns are also important. Current wind resource assessments could greatly benefit from application of advanced modeling and computational methods and work in climate modeling and prediction.

9) Catalysis for Energy Efficiency and Renewable Energy

Implications: Although there is good cooperation in catalysis work, there remain significant opportunities to apply the energy savings potential of catalysis to energy supply and demand challenges. There are also important implications for other departmental missions, but clearly one of the high priority initial thrusts should reflect the significant opportunities to impact energy-related processes and technologies that will remain cost-prohibitive until breakthroughs in areas of catalysis are realized. Advances in catalysis are now possible through new facilities that can examine in real-time, chemical interactions at the molecular scale and at extremely fast intervals.

Promising focus areas: Significant opportunities exist in industrial technologies, transportation, energy supply and conversion (including biomass), and more.

10) Nuclear Fuel Materials and Design

Implications: Current materials synthesis efforts here, too, are driven by a "cook and look" approach. Basic research could help significantly with the design and predictive modeling and evaluation of various nuclear fuel materials and configurations. Such work is critical to next generation reactor concepts and designs, as well as for verification and its associated costs and uncertainty.

Promising focus areas: There are many areas where basic research could be helpful. Some areas of high interest include high temperature and corrosion resistant materials, helium contaminants and impacts, sulfur iodine in H_2 production, cladding interactions, and performance characteristics of high temperature liquid salts.

11) Catalysis for Hydrogen Production from Nuclear Energy

Implications: As part of advanced concepts for commercial hydrogen production, there are many unanswered questions and technological uncertainties that could benefit from science investigations. Research is needed to develop catalysts and membranes that would improve hydrogen production efficiencies and make the technology cost effective. Catalysts and membranes employed thus far in laboratory demonstrations are either excessively expensive to produce or provide too short a service life for future commercial applications.

Promising focus areas: Current platinum catalysts sinter at high temperatures and the platinum is lost. Research is needed not only to address this problem but to explore new and/or alternative catalysts that have the desired properties and can function in these hostile, high-temperature conditions. In addition, membranes for a variety of applications including improving equilibrium conversions, difficult chemical separations, dewatering, and hydrogen purification will improve hydrogen production efficiency and cost effectiveness. Improved catalysts and membranes are also required for the electrolyte steps in themochemical cycles.

12) Risk Assessments for Geologic Carbon Sequestration

Implications: There are reasonably good models for the geologic performance of oil fields spanning a 30-40 year period. However, detailed understanding and models for other geologic storage reservoirs is insufficient to allow for long term risk assessment predictions. A challenging question is how to predict the performance of geologic sequestration of CO_2 spanning periods of 100 years or more. There are complex chemistry and geosciences issues that must be studied further and factored into models. And there is a need to correlate small, focused tests with model development. Ultimately, our ability to use fossil fuels may be constrained by our ability to pursue one or more carbon sequestration pathways and, thus, our ability to predict the performance of engineered sequestration pathways, such as geologic carbon sequestration, takes on a real sense of urgency.

Promising focus areas: Basic research is needed in all aspects of geosciences and geology. Additionally, advanced modeling and simulation are critical areas of basic research need, including risk assessment in complex systems which are driven by non-linear dependencies. Further areas of basic research needs include trapping mechanisms, including pore trapping, chemical reactions, and lab-field reconciliation. The chemistry of cement-based materials is also of critical interest given the expected dependency on concrete caps that will need to withstand the complex chemistry of contaminants and CO2 for considerably long times. Also beneficial for risk assessment in geologic carbon sequestration will be DOE's efforts to understand, model, and predict fundamental subsurface biogeochemical processes, including collaboration with DOE's SciDAC program in the context of contaminant mobility. One of the SciDAC projects in subsurface modeling will have specific applicability to geologic carbon sequestration.

13) Gasification and Combustion Modeling and Computational System Dynamics

Implications: There are significant technical issues in understanding and optimizing the fundamental, basic mechanisms associated with coal gasification and combustion that will benefit greatly from supporting basic research.

Promising focus areas: Areas of basic research need include: reactive flows and combustion, both requiring a finer "grid" size and model scaling; problems associated with the high flame speeds of hydrogen; and the need for better codes to model combustion and turbine dynamics. In particular, efforts undertaken within the Innovative and Novel Computational Impact on Theory and Experiment program may be helpful, and modeling from the micro to the macro will undoubtedly yield benefits for Future/Gen.

14) Advanced Sensors and Controls for Gasification and Combustion Systems

Implications: For a broad range of future coal gasification and combustion systems, they will need to respond rapidly, and in real-time, to changes in combustion and fuel quality to balance such factors as performance with emissions, addressing contaminants such as mercury and others. It isn't just research into advanced sensors that is required, but research into the algorithms that underpin intelligent control systems that can respond instantaneously to sensor data.

Promising focus areas: There are opportunities to further develop and apply capabilities in scaling and reduced order modeling. The Department is faced with some of the same challenges in grid control, that is, how and where to deploy smart sensors and how to deploy mathematics simplification techniques to separate noise from real changes in control systems - responding at very rapid speeds. Additionally, there is room for further development of smart sensors that can withstand harsh, corrosive and high temperature environments.

15) High Performance Materials for Advanced Fossil Energy Processes

Implications: Although there is considerable scientific work underway within DOE to develop materials that can withstand harsh conditions, there are particular needs in fossil energy due to the temperatures, pressures, and corrosive and abrasive environments posed by fossil fuel processing, conversion, and combustion. Additional basic research to support those applied energy challenges will help improve existing systems, and deliver the new fossil energy systems that will improve efficiency and reliability of the next generation plants.

Promising focus areas: There is particular opportunity to explore fractures, cracking, corrosion, atomic displacement and scaling.

NATIONAL NUCLEAR SECURITY

16) Innovative Materials for Safeguards and Security

Implications: There are myriad technical challenges in safeguards and security that would benefit considerably from advances in materials science. Such new materials would enable more rapid threat detection, enhance and harden communications, protect personnel, and isolate and protect special nuclear materials.

Promising focus areas: New materials are needed for lightweight armor, high efficiency filtration (chem/bio filters), physical barriers, perimeter sensors and more.

17) Nuclear Test Detection

Implications: Presently, there are reasonably good detection systems and processes for above-ground tests although there is room for improvement. Detection of below-ground tests, however, is more challenging and is handicapped by limitations in seismic and geologic models and characterization, as well as the ability to discriminate from the background noise of natural seismic disturbances. Especially for low-yield testing, close proximity to underground tests is required, posing a significant obstacle when attempting to monitor rogue nations. Space-based nuclear explosion monitoring poses some challenges as well.

Promising focus areas: Research is needed in seismic analysis, earth models, and the space weather environment.

18) Remote Sensing and Analysis of Radioactive Materials and Nuclear Weapons

Implications: Preventing the proliferation, production, diversion, transport, and assembly and use of radioactive weapons and detection and tracking of significant radioactive materials is a critical responsibility of the DOE and a scientific and technological challenge. With the expansion of terrorism, and the ability of developing nations to produce such materials, the challenges have never been greater, and the risks higher. There is opportunity for the DOE's basic research communities to work together to further strengthen our nation's sensing and analysis capabilities. A critical challenge is the ability to "see" highly shielded HEU, where even gammas see little or no penetration.

Promising focus areas: Research is needed in materials science and large, defect-free crystal growth for detectors; simplifying computational algorithms for analyzing gigabytes to terabytes of data from hyper-spectral analyses; hierarchy of decay of higher energy lines of isotopes and resulting cross-sections; neutrino detection for nuclear plants.

ENVIRONMENTAL MANAGEMENT

19) Chemistry and Separations for Radioactive Waste

Implications: There are critical unanswered scientific questions that must be addressed to facilitate the stabilization, long-term storage, treatment, and ultimate disposal of radioactive waste. The chemistry underlying these wastes is extremely complex and separations processes designed to split the highly problematic fractions of the waste from other portions is poorly understood. Many of these wastes are merely prepared for long-term stabilization at this time. Significant cost savings will only be made possible through improved scientific understanding of these complex chemical interactions.

Promising focus areas: There are many complex chemistry issues of interest, ranging from modeling separations and chemical reactions (similarities between waste management and advanced fuel cycle work within DOE), to understanding the interaction of radioactive wastes and soils, to the behavior of low level waste grout over hundreds or even thousands of years. In addition, there are material science issues associated with the long-term performance of aging storage tanks and with potential grouts for those tanks. Fossil energy applications could also benefit from understanding the chemistry of concretes, especially when subjected to radiation environments. Similarly, transuranic chemistry is all but terminated in the Department and it provided an important foundation for work in waste management, nuclear energy, and other mission areas within DOE. Fundamental science in the area of monitoring and sensors is needed to provide tools for the long-term stewardship of these materials and their storage environments.

20) Modeling, Simulation, and Scaling Issues for Environmental Management

Implications: Consistent with the current joint attempts at groundwater modeling at Hanford by DOE's basic research and environmental management communities, there are numerous other areas within the latter community that would benefit from the application of advanced understanding of subsurface transport processes, computation and scaling methods to provide insights into the processes and designs for treatment and disposal, and ultimately, for validation of the same.

Promising focus areas: Evaluation of subsurface fate and transport, disposal forms and stability, interaction with the environment, and predictive validation of performance are just some of the opportunity areas.

21) Predicting High Level Waste System Performance over Extreme Time Horizons

Implications: Predicting the performance of combined engineered and natural containment barriers as part of a systems perspective for high level waste management is a challenging task when asked to examine performance over tens of thousands or even a million years. It is entirely possible, however, to design for such long time horizons if conservative assumptions are made at each step of the way. There may be opportunity to apply areas of science to reduce the uncertainty associated with the full system performance. This could translate into less costly approaches.

Promising focus areas: Particularly promising areas include application of lessons learned and synergies between the DOE's radioactive waste programs and DOE's science communities on studies of the subsurface transport of materials, basic energy sciences work on materials corrosion, including corrosion properties of new advanced materials; synthesis compositional approaches to developing new radiation-high temperature-chemically resistant materials for use in long-life monitoring sensors; high temperature materials properties such as might be presented by magma intrusion; understanding of nuclear cross-sections; access to nuclear data that could be useful for further validating the unlikelihood of criticality; and enhanced understanding of climate variability (including paleoclimate and future predictive modeling).

III. STRATEGIES FOR IMPLEMENTATION

The Energy Policy Act, Section 994(b), requires the Secretary of Energy to "develop a coordination plan to improve coordination and collaboration in research, development, demonstration, and commercial application activities across Department organizational boundaries." That Plan was to include, as detailed in Section 994(c1-4), the following four elements:

1. The crosscutting scientific and technical issues that span more than one program or major office.
2. Ways that the DOE applied technology programs are coordinating their activities and addressing the crosscutting issues.
3. Ways to improve the technical interchange within the Department, including ways in which the research agenda of the Office of Science and the applied programs can interact and assist each other.
4. A description of how the Secretary will ensure that fundamental research is integrated into DOE's applied technology programs.

The foundation and substance for items 1-3, above, have been developed through the R&D Council and the Program Reviews that were held in May and June 2006. These activities, along with plans for follow-up on 21 significant issues and opportunities, are described in detail in Chapter II of this report. This final chapter, Chapter III, provides our strategies for ensuring continued progress in pursuit of research integration at the DOE and addresses item 4, above.

DOE's Coordination Plan, and our approach for the future, is built around the principle that integration efforts must support DOE missions and must reduce risk. Ultimately, this is an evolutionary process and validation of DOE's Coordination Plan will be realized through a determination of our success in pursuing the expanded opportunities identified in Chapter I, and the new, 21 opportunities identified in Chapter II.

The crosscutting, senior level dialogue facilitated by the S&T Program Reviews was a significant extension of past and ongoing coordination efforts and an important step toward the goal of more effective Departmental research integration. Looking forward, and to maintain quality, the DOE must continue progress while preserving the distinct mission identities of individual programs. DOE's intent is not to blur those mission focuses in order to fill R&D gaps, but rather, to explore the areas of connectivity and mutual benefit that come from enhanced cooperation. If done correctly, cooperation will result in mutual benefits for both the science and applied technology programs.

In pursuit of this overarching theme of mission focus, and with the goal of ensuring our continued improvement and success over time, the DOE plans to pursue 10 key strategies as noted below.

Ten Strategies for Improving Coordination and Collaboration

1. Communicate and reinforce the importance of coordination and collaboration at the highest levels within the Department, beginning with emphasis in DOE's 2006 Strategic Plan.

2. Create an environment that enhances cooperation and collaboration in advancing DOE's missions.

3. Facilitate cooperation at all levels in the Department, from the facilitation of structured dialogue among DOE's senior management, to the pursuit of the highly successful approach of technical workshops, to the encouragement of ad hoc and informal interactions among staff at all levels within the Department.

4. Commit to follow-through and track performance, with reasonable timelines for success.

5. Preserve the distinct mission focus of individual programs while exploring areas of connectivity and mutual benefit.

6. Seek technical input on opportunities from a broad spectrum of the DOE S&T community and stakeholders.

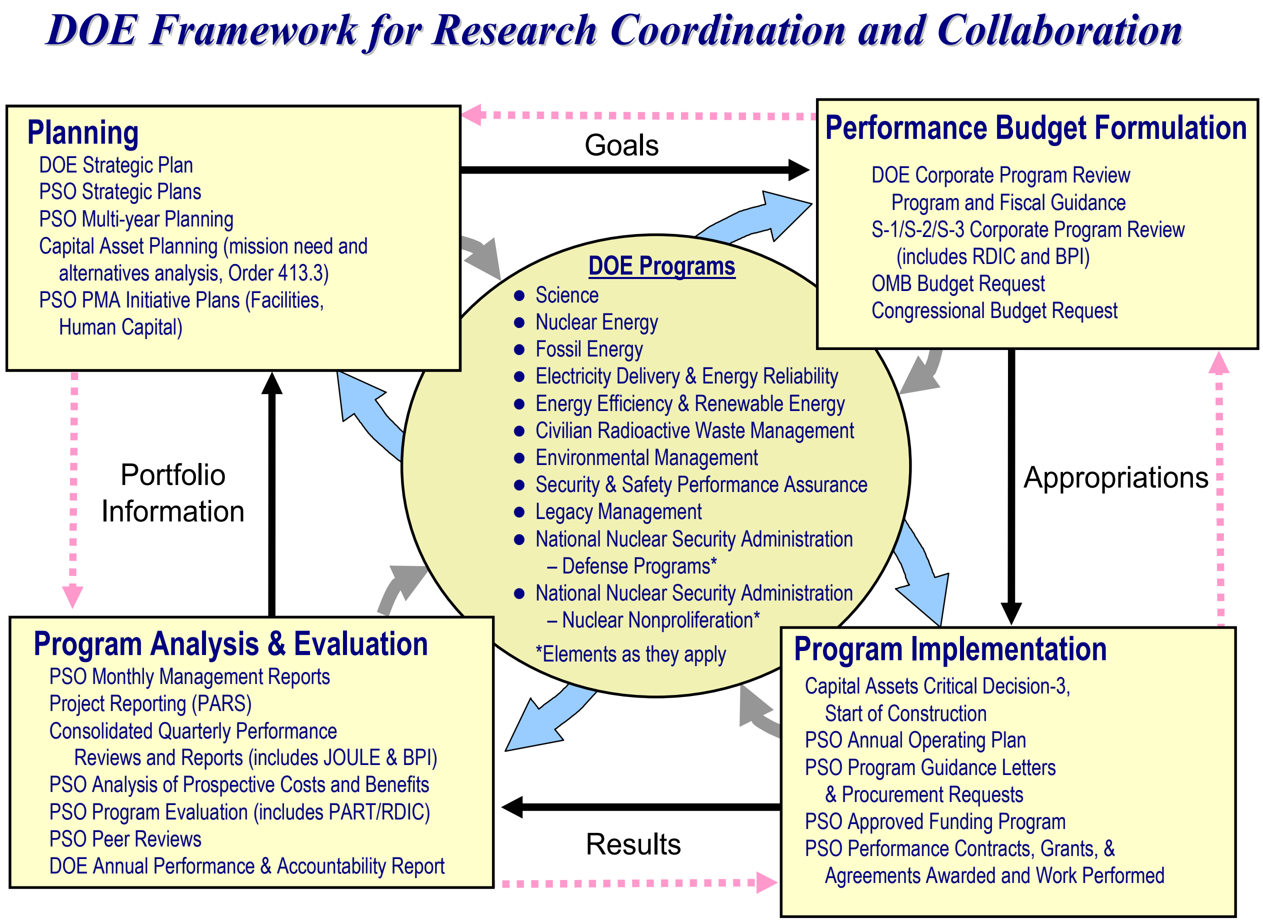
7. Reduce "impedance mismatches" to ensure that the primary organizations have the capabilities to function as effective partners so that coordination and collaboration can happen in meaningful ways, and/or that the required programmatic handoffs can take place.

8. With particular emphasis on the early stages, pursue improvements in the process, from conceptualization through program evaluation.

9. Pursue the analytic tools and methodologies that will help to improve portfolio decisions.

10. Accept some risk for failures in order to encourage innovation and transformational science and technology.

Beyond the discrete strategies noted above, the Department views the need for improved research coordination and collaboration in a systems context. A conceptual framework, provided below, identifies the various stages and opportunities for constructive intervention. Not all of the specific areas identified offer the same opportunities, or opportunities for all programs. Nevertheless, this framework serves as a starting point for exploring a broader range of coordination and collaboration.



As we look to the immediate future, three priorities will guide our next steps. These priorities include:

1. Strengthen and Build Upon Existing R&D Integration Mechanisms: Chapter I of this report provides details about existing R&D integration mechanisms and processes. As DOE gains experience through the R&D Council and Program Reviews, and as the Department brings the 21 crosscutting opportunities to maturity, improvements and changes to those mechanisms will be made. A major focus will be on strengthening the handoff of research results in both directions – science-to-technology, and technology-to-science – in order to avoid "impedance mismatch" as discussed in Chapter I.

2. Ensure that Senior DOE Management is Fully Engaged in the Plan: Section 1006 of EPAct creates the Under Secretary for Science and invests that office with wide ranging responsibilities to advise the Secretary of Energy on science and technology matters, monitor R&D programs, and advise the Secretary on "long-term planning, coordination, and development of a strategic framework for Department research and development activities." As a result, DOE has created an R&D Council to ensure that senior management is focused and engaged on R&D integration activities. Ultimately, the various discrete Program Review and portfolio assessment exercises conducted as part of

this first cycle (and as described in this report) will provide lessons learned that can improve the process in subsequent cycles.

3. Advance Research Integration Workshops on Select Topics: As discussed in Chapter I, technical workshops enjoy a special role as launching venues for crosscutting efforts. Some workshops have just taken place and many additional workshops are planned over the next few months and into 2007 in response to the Program Reviews conducted during the month of May, 2006.

As previously noted, achieving research integration is not an easy matter. Nevertheless, DOE is off to a strong start and is committed to pursuing the right combination of opportunities and incentives that will facilitate cooperation and the realization of mutual benefits among DOE's R&D programs.

APPENDIX

List of Acronyms

AEI	Advanced Energy Initiative
AFCI	Advanced Fuel Cycle Initiative
ASCR	Advanced Scientific Computing Research (of the Office of Science, DOE)
BER	Biological and Environmental Research (of the Office of Science, DOE)
BES	Basic Energy Sciences (of the Office of Science, DOE)
BPI	Budget & Performance Integration
CCTP	Climate Change Technology Program
CO2	Carbon dioxide
DOD	Department of Defense
DOE	Department of Energy
DTRA	Defense Threat Reduction Agency
EERE	Office of Energy Efficiency and Renewable Energy (of the DOE)
EM	Office of Environmental Management (of the DOE)
EMaCC	Energy Materials Coordinating Committee
EOR	Enhanced Oil Recovery
EPAct	Energy Policy Act of 2005
EPSCoR	DOE Experimental Program to Stimulate Competitive Research
FE	Office of Fossil Energy (of the DOE)
FY	Fiscal year
FES	Fusion Energy Sciences (of the Office of Science, DOE)
GNEP	Global Nuclear Energy Partnership
HEDP	High Energy Density Physics
HEP	High Energy Physics (of the Office of Science, DOE)
HEU	highly enriched uranium
IWG	Interagency Working Group
LEDs	Light-emitting diodes
LLNL	Lawrence Livermore National Laboratory
MEWG	Interagency Working Group on Metabolic Engineering
NAS	National Academies of Science
NASA	National Aeronautics and Space Administration
NE	Office of Nuclear Energy (of the DOE)
NIF	National Ignition Facility
NNSA	National Nuclear Security Administration (of the DOE)
NSTC	National Science and Technology Council
NOx	Nitrous Oxide
NP	Nuclear Physics (of the Office of Science, DOE)
NSF	National Science Foundation
OLEDs	Organic light-emitting diodes
OE	Office of Electricity Delivery and Energy Reliability (of the DOE)
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory
OSTP	White House Office of Science and Technology Policy
PART	Program Assessment Rating Tool

PARs	Performance and Accountability Reports
PSO	Program Secretarial Officer
RDIC	Research & Development Investment Criteria
RW	Office of Civilian Radioactive Waste Management (of the DOE)
R&D	Research and development
SBIR	Small Business Innovative Research Program
SC	Office of Science (of the DOE)
SciDAC	Scientific Discovery through Advanced Computing (of the Office of Science, DOE)
SIAM	Society for Industrial and Applied Mathematics
SNL	Sandia National Laboratory
SOx	Sulfur Oxides
SRS	Savannah River Site
SSA	Office of Security and Safety Performance Assurance (of the DOE)
STTR	Small Business Technology Transfer Program
S&T	science and technology
S-1/S-2/S-3	Secretary, Deputy Secretary, and Under Secretary of Energy, respectively